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Biological Treatment of Hazardous Aqueous Wastes

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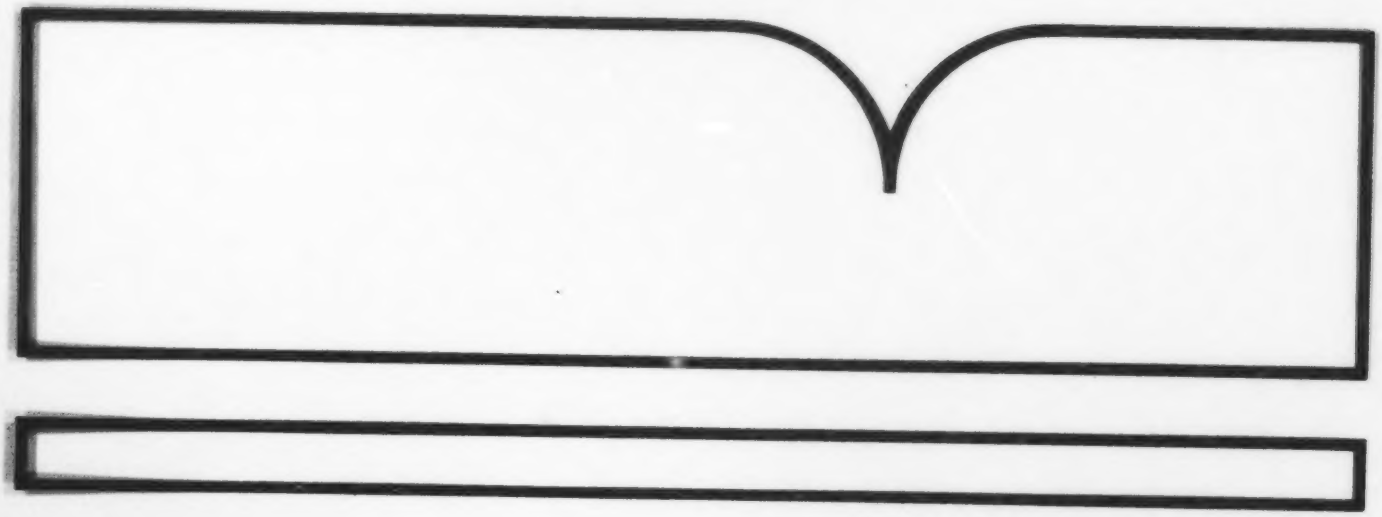

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BIOLOGICAL TREATMENT OF HAZARDOUS AQUEOUS WASTES

by

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16. ABSTRACT

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A series of batches were run with primary effluent from the City of Cincinnati's Mill Creek Sewage Treatment Facility (MCTF) to develop a biomass on the disks and to obtain kinetic removal rate data. These runs were then followed with experiments utilizing leachate that:

- Operated at various ratios of leachate to primary effluent
- Operated at 100% leachate
- Determined the final effluent quality
- Determined the fate of specific organic compounds
- Determined the rate of removal

This paper reports on the results from these experiments and the effectiveness of an RBC to adequately treat leachates from Superfund sites.

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Studies have been conducted with a rotating biological contactor (RBC) to evaluate the treatability of leachates from the Stringfellow and New Lyme hazardous waste sites located in Riverside County, California and Ashtabula County, Ohio, respectively. The leachates were transported from the waste sites to Cincinnati, where a pilot sized RBC was installed at the United States Environmental Protection Agency's Testing and Evaluation (T&E) Facility.

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This paper reports on the results from these experiments and the effectiveness of an RBC to adequately treat leachates from Superfund sites.

Background

The need to destroy or convert toxic organic chemicals to harmless materials is gaining acceptance. Land disposal is no longer regarded as an ultimate solution for disposing of organic waste because of the potential for leachate formation or groundwater contamination. Leachate releases have taken place from uncontrolled waste disposal sites and provisions are needed to remedy these situations.

Biodegradation of the organics present in leachate may provide an acceptable and cost effective process for treating leachates. For these reasons a study was initiated at the U. S. Environmental Protection

Agency Testing and Evaluation Facility in Cincinnati, Ohio to evaluate a rotating biological contactor[6] to reduce the level of organics in leachates.

Leachate Sources

The initial evaluations were conducted with leachates from Stringfellow, CA, and New Lyme, OH.

Stringfellow is a Superfund site[1] that is located in Glen Avon, California near Riverside, California. The leachate is generated at an approximate rate of 96 m^3/d (25000 gal/d) and contains high concentrations of metals and organics. A leachate treatment facility (1) at the site includes lime treatment for metals removal, followed by clarification, sand filtration, and granular carbon treatment for organics reduction. The effluent from the carbon beds is trucked 19 km (12 mi) to an Orange County interceptor sewer for disposal into the municipal sewer system.

New Lyme is a Superfund site located in Ashtabula County, Ohio (2,3). The landfill received household, industrial, commercial and institutional wastes between 1969 and 1978. Groundwater moves upward through the bedrock into the landfill and under artesian conditions percolates through the landfill and flows out through seeps into the surrounding wet lands.

Project Description

A pilot sized RBC for evaluating the biochemical treatability of Superfund sites' leachates was installed at the EPA Testing and Evaluation Facility located at the Mill Creek Treatment Facility in Cincinnati. The pilot sized RBC contains 1000 m^2 (11000 sq ft) of surface area which is approximately 10% of a full scale RBC(4). The diameter of the pilot unit is 3.6 m (12 ft), which is identical to a full scale RBC. The length is less than 1 m (3.3 ft), whereas a full scale RBC is 7.6 m (25 ft). The MCTF's primary effluent (PE) was used to develop a biological population on the RBC disks and to obtain basic kinetic data on the removal rate of dissolved organic chemicals(5). The ideal conditions would have involved using leachate from the sites to develop an indigenous biomass. However, the logistics favored the treatment plant's PE because of the distance between Cincinnati and the hazadous waste sites. There were other factors which favored conducting the experiments in Cincinnati such as the auxilliary support available for installation, chemical analyses, 24 hour monitoring, and the availability of specialists on biochemical treatment for consulttion. The leachates were trucked from the Superfund sites to Cincinnati for experimentation and pumped to a storage tank. The Strinfellow leachate was lime treated at the California site for metals reduction so that the experiments could concentrate on soluble organics removal with the RBC facility. The New Lyme leachate did not require treatment to reduce the level of metals.

The pilot RBC was designed to operate in a batch mode for the following reasons:

- Eliminate flow controls
- Minimize spillages
- Minimize accidental releases into the T&E sewer systems
- Improve mass balance analyses
- Obtain reaction kinetics data
- Control final disposal
- Scale-up for site operation

Objective

The prime objective of this project was to determine whether leachates can be economically converted into innocuous wastes by biochemical treatment with a rotating biological contactor.

Methodology

The RBC was initially operated with primary effluent supplied from the Mill Creek Treatment Facility to develop an adequate biomass on the RBC disks in preparation for leachate treatment.

The first experimental batches for each site were made with increasing ratios of leachate/RBC-treated primary effluent to allow a gradual acclimation period of the biomass to the leachate. Following these batches the runs were made with 100% leachate. A flow schematic of the RBC pilot plant is shown in the attached Figure 1. The operation consisted of transferring the leachate from the storage tank to the mix tank where the volume was determined. It was then pumped to the RBC and operated at a speed of 1.5 rpm. The experiment was considered complete when the dissolved organic carbon (DOC) reached a constant level. For the Stringfellow leachate, the RBC contents were then returned to the mix tank for additional treatment with activated powdered carbon (APC) followed by clarification with ferric chloride to achieve the effluent standards required for disposal to the MCTF. For New Lyme leachate the effluent from the RBC underwent normal clarification before disposal into the sewer system leading to the MCTF.

The effluent limitations set by the MCTF were:

- Total organic halides (TOX) $\leq$5 mg/L
- Vapor space organics(6) (VSO) $\leq$300 ppm
- $6 \leq pH \leq 10$

Internal limits were also set on gross organics that were in essence equivalent to a relatively high strength raw wastewater. These limits were:

- Soluble biochemical oxygen demand, SBOD $\leq$100 mg/L
- Dissolved organic carbon, DOC, $\leq$100 mg/L
- Soluble chemical oxygen demand, SCOD, $\leq$300 mg/L

During the experiment the following operating parameters were monitored:

- Volume of leachate fed to the RBC
- Temperature, every 2 hours
- Speed of rotation, every 6 hrs.
- Visual comments on thickness and color of biomass, every 2 hours
- Dissolved oxygen, every 2 hrs.
- pH, every 2 hours
- SBOD, DOC, SCOD.

Kinetic Parameters

During both the biomass build-up and the leachate experiments, samples were obtained from the RBC tank at specified time intervals to obtain a kinetic curve showing the disappearance of the soluble gross organics with time. The gross organics monitored included SBOD, DOC, and SCOD. During each experiment the DOC samples were analyzed immediately to obtain instant information on the progress of the reaction.

In addition to the gross organics the raw leachate and the

treated effluent were analyzed for:

- Suspended solids, (SS)
- Volatile suspended solids, (VSS)
- Nitrogen series, including Kjeldahl, ammonia, nitrite, and nitrates
- Phosphorus, (P)

Specific organic analyses were also obtained for the following chemicals on Stringfellow leachate:

- Para-chlorobenzene sulfonic acid (PCBSA)
- 1, 2 dichlorobenzene
- O-xylene
- Chloroform
- Ethylbenzene
- 2-hexanone
- Tetrachloroethylene

Specific organic analyses obtained on New Lyme leachate and effluent included:

- Priority pollutants
  - volatile compounds
  - base-neutral compounds
  - metals
  - acid compound
  - pesticide and PCB compounds

Results and Discussion

The rate of soluble organic removal was determined for the Mill Creek primary effluent by following the disappearance of SBOD, SCOD and DOC with time. A typical curve for the disappearance of soluble organics using PE was used as a base (see Figure 2) for comparison with data obtained on PE following experiments with leachate, to determine if the biomass had undergone deterioration by the leachate. See Figure 3 and compare this result with Figure 2 as an example of the drop in removal rate following an extended experimental batch with leachate.

Biomass Acclimation

Since the biomass established on the RBC disks was developed with primary effluent, acclimation runs were made using the leachates diluted with primary effluent to avoid shock loading the biomass with 100% leachate. The Stringfellow leachate was three to four times stronger in organic concentrations than the PE and contained a significant quantity of p-chlorobenzene sulfonic acid, (PCBSA) a compound that is foreign to the biomass. The New Lyme leachate was 20 times stronger in organic concentration than PE.

The acclimation period consisted of experimental runs using progressively stronger concentrations of leachate as shown below.

The ratio of leachate to PE

For Stringfellow

- Batch # 1: Leachate/treated PE = 1/2
- Batch # 2: Leachate/treated batch # 1 = 1/1
- Batch # 3: Leachate/treated batch # 2 = 3/1

For New Lyme

- Batch # 01: Leachate/PE = 1/2
- Batch # 02: Leachate/PE = 2/1

When Stringfellow leachate was combined with treated PE in batch # 1 there was a six day lag period before the DOC began to disappear. (See Figure 4.) After the incubation period the reaction required approximately 2 days to obtain a drop of approximately 60% in the DOC. The residual DOC, approximately 50 mg/L, remained unchanged

during an additional 6 days of treatment.

In batch # 2 the reaction for the disappearance of DOC began after the first day and was essentially complete after three days. The percent removal of DOC was approximately 50% and the residual DOC was approximately 90 mg/L. The result for batch # 3 was similar to batch # 2. That is, the reduction in DOC was essentially complete after three days. The DOC removal was approximately 55% and the batch had a final DOC of 120 mg/L.

Batch # 3 was continued for an additional 27 days to determine if an extended time period would result in a further reduction in DOC The additional time had no effect on DOC. However, this added reaction time resulted in the sloughing off of the biomass and was the cause of the drop in reaction time when PE was tested to determine the reaction rate, as shown in Figure 3.

When New Lyme (NL) leachate was mixed with PE at a ratio of 1 part NL/ 2 parts PE, the reaction started immediately and the organics were converted to innocuous products in less than 20 hours. (See figure 5.)

The removal was 97% for the gross organics and the quality of effluent was far superior to many secondary effluents from wastewater treatment plants when compared on the basis of final gross organic concentrations.

Batch # 02 had radically different results. The NL/PE ratio was increased to 2/1 and there was an ineffective rate of removal. The results indicate:

- The removal progressed at a very slow rate, as depicted in Figure 6. Instead of 20 hours of reaction time, it took 300 hours to complete the reaction.
- The biomass was stripped from the discs. This was evident by visual observation of the suspended solids. To confirm this, a run was made using PE. Figure 7 shows that the disappearance of the organics was at a significantly lower rate of removal in contrast to the satisfactory results obtained earlier with PE. Since the speed of rotation for all runs was made at 1.5 rpm it was assumed that the oxygen transfer rates were unaffected (7). The substrate concentration using PE was similar, so the only factor remaining that could cause the fall-off in organic disappearance was the biomass level. This supported the visual evidence of biomass stripping and the increased concentration of the suspended solids in the RBC tank contents.

Operation with 100% Stringfellow Leachate*

Following the Stringfellow acclimation runs, a series of experiments were made using 100% Stringfellow leachate. The results were similar to those obtained during the acclimation runs 2 and 3. (See Figure 8.)

- Approximately four days were required to reduce the DOC from 300 to 100 mg/L. This closely approximates the

*As of this writing no runs have been made with 100% New Lyme leachate.

results obtained with the leachate and PE mixture and is in contrast to only 2 hours that is needed to obtain a large DOC reduction using PE.

- The removal rate was significantly below the rate obtained with PE. Previous work on RBC's showed a SBOD removal rate of 440 mg/h·m^2 (4) (41 mg/h·ft^2) with municipal wastewater; whereas the Stringfellow leachate gave 19 mg/h·m^2. (1.7 mg/h·ft^2).
- The RBC operation required pH adjustment. As the DOC dropped during the reaction phase the pH would fall and require periodic additions of sodium hydroxide to maintain a pH greater than six.
- It was necessary to add sodium phosphate to the leachate to provide adequate levels of P to maintain a satisfactory supply of nutrients (8).
- Characterization of the leachate indicated that nitrogen was readily available as nitrate and therefore no adjustment was needed in regard to nitrogen.
- The major identified organic constituent, p-chlorobenzene sulfonic acid, was readily removed during the RBC treatment.
- The residual DOC was not identified by a GS-MS scan, because of the nature of the compound/compounds.
- The leachate final concentrations were

  110 mg/L of DOC
  1 mg/L of SBOD
  370 mg/L of SCOD

These results showed almost 100% removal of biodegradable organics as defined by SBOD. They also showed that a significant fraction of refactory organics remained after the treatment. Only 63% of the DOC was removed and only 54% of the SCOD was removed.

In order to meet the limits specified for disposal into the Mill Creek Treatment Facility, it was necessary to treat the leachate with activated powdered carbon to remove additional refractory organics. The RBC contents were transferred to a mix tank where 12 to 15 grams of activated carbon per gram of DOC were added. Separation of the carbon from the leachate was achieved by flocculation with ferric chloride during clarification. The previously specified limits were met:

- TOX <5 mg/L
- VSO < 300 ppm
- 6<pH<10
- DOC <100 mg/L
- SCOD <300 mg/L
- SBOD <100 mg/L

Conclusions

Although the organics in Stringfellow leachate were not totally biodegraded, a significant reduction was achieved. The DOC was reduced by two thirds, the SCOD was reduced by one-half, and the SBOD was completely eliminated.

The refractory fraction following RBC treatment was not identified by a GC-MS scan and the organics constituting 1/3 of the total organics at Stringfellow remains unidentified.

Leachates from different hazardous waste sites have unique compositions, and it can be expected that each will react differently to RBC treatment. The leachate characterization is important to obtain an indication of its biodegradability. The experience with Stringfellow showed the pH dropped as the reaction

progressed, yet at New Lyme the pH rose, so the behavior is not predictable. The DO levels were satisfactory, usually above 5 mg/L, with both leachates indicating that biomass levels were probably controlling the reaction kinetics. The reaction rates were significantly different when comparing the two leachates. At Stringfellow the reaction rate required approximately 4 days to convert the SBOD, whereas New Lyme required only 20 hours and yet the initial SBOD concentrations were three-fold higher than Stringfellow. With New Lyme leachate, increasing the ratio of NL/PE from 1/2 to 2/1, significantly affected the reaction rate, possibly indicating either an inhibiting organic or insufficient nutrients.

It is clear that the RBC offers a high degree of promise for cost effectively treating leachates from hazardous waste sites; however more research is needed to confirm these findings and to better define the effectiveness of the RBC treatment of leachates.

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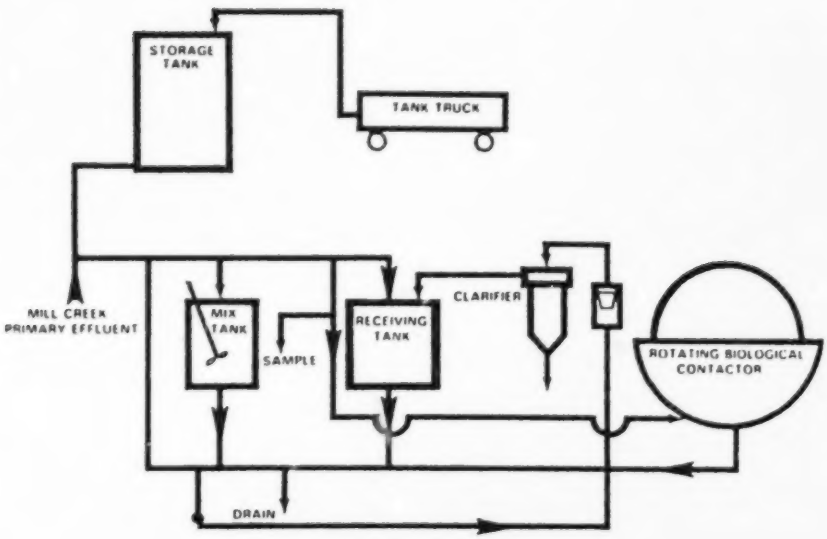


Figure 1 Stringfellow—RBC Flow Schematic

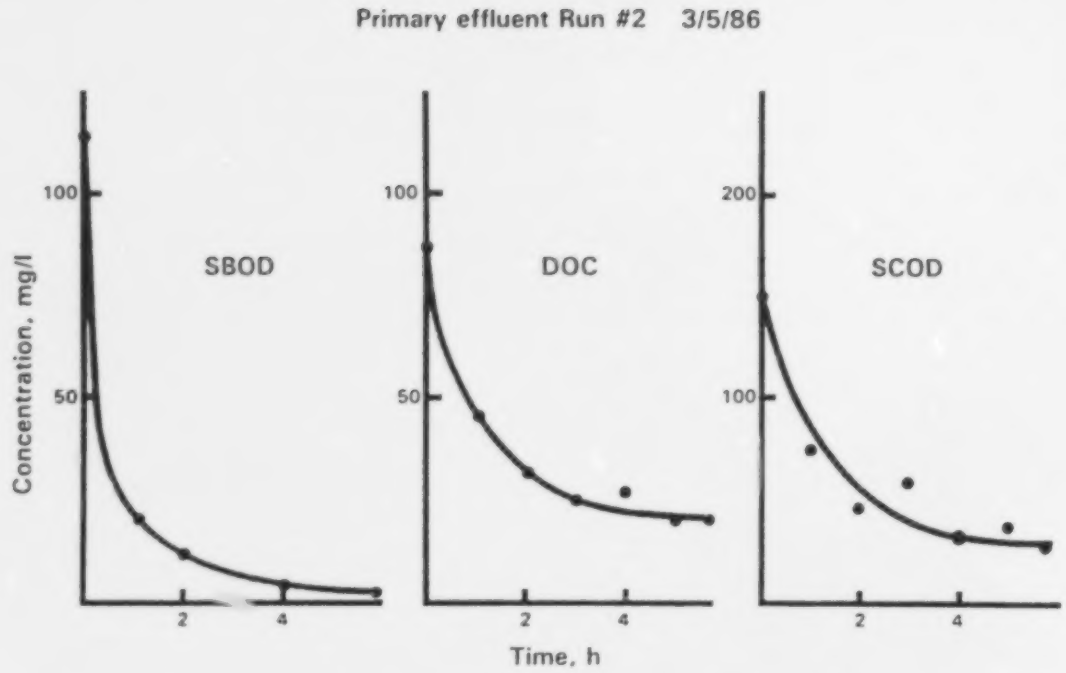


Figure 2 Standard Rate for the Biodegradation of Primary Effluent

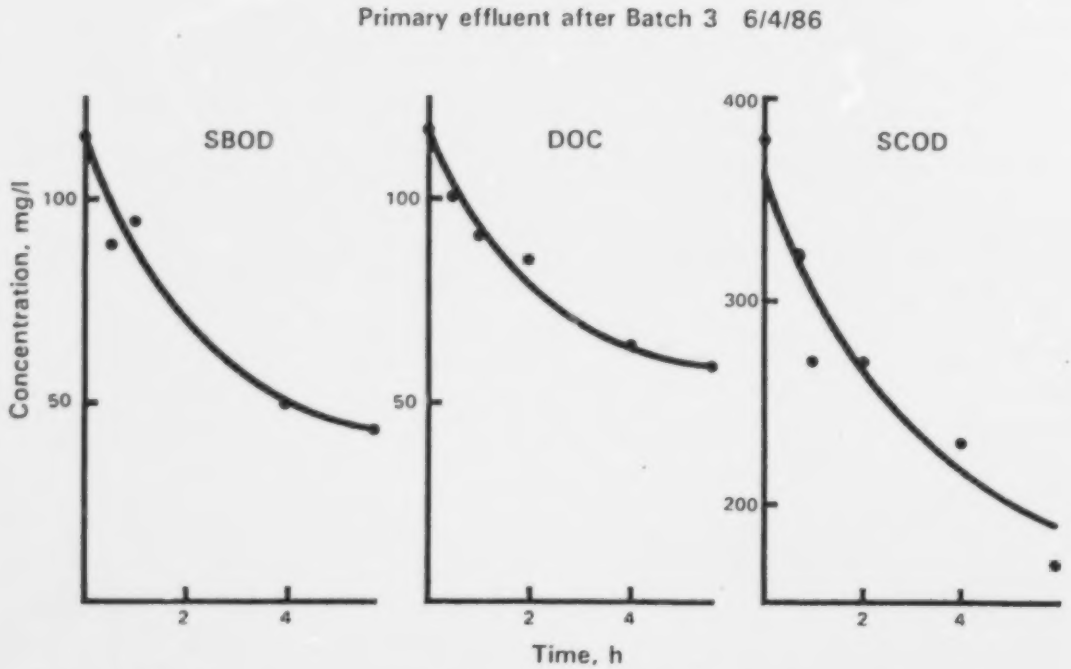


Figure 3 Disappearance of Organics After Stringfellow Run-03

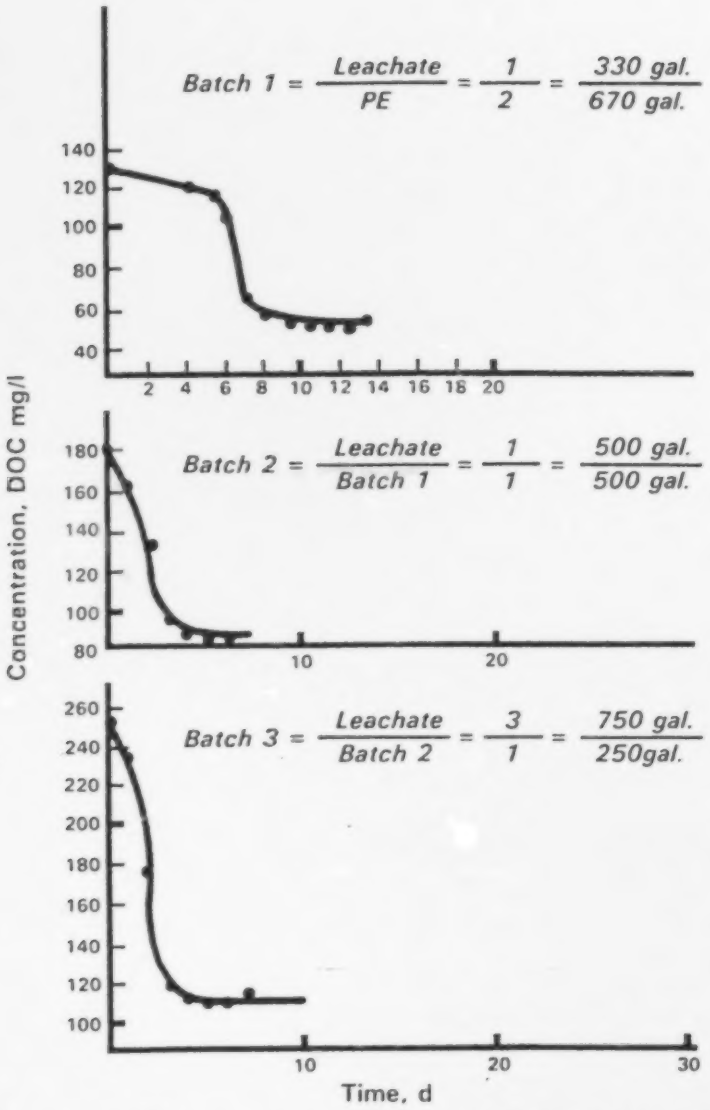

Batch 1 = Leachate / PE = 1 / 2 = 330 gal. / 670 gal.
Batch 2 = Leachate / Batch 1 = 1 / 1 = 500 gal. / 500 gal.
Batch 3 = Leachate / Batch 2 = 3 / 1 = 750 gal. / 250gal.
Concentration, DOC mg/l
Time, d

Figure 4 Disappearance of DOC With Time Using Various Ratios of Leachate to Treated Effluent

Figure 5 Disappearance of Organics with New Lyme Leachate

Run-01 NL/PE = 1/2

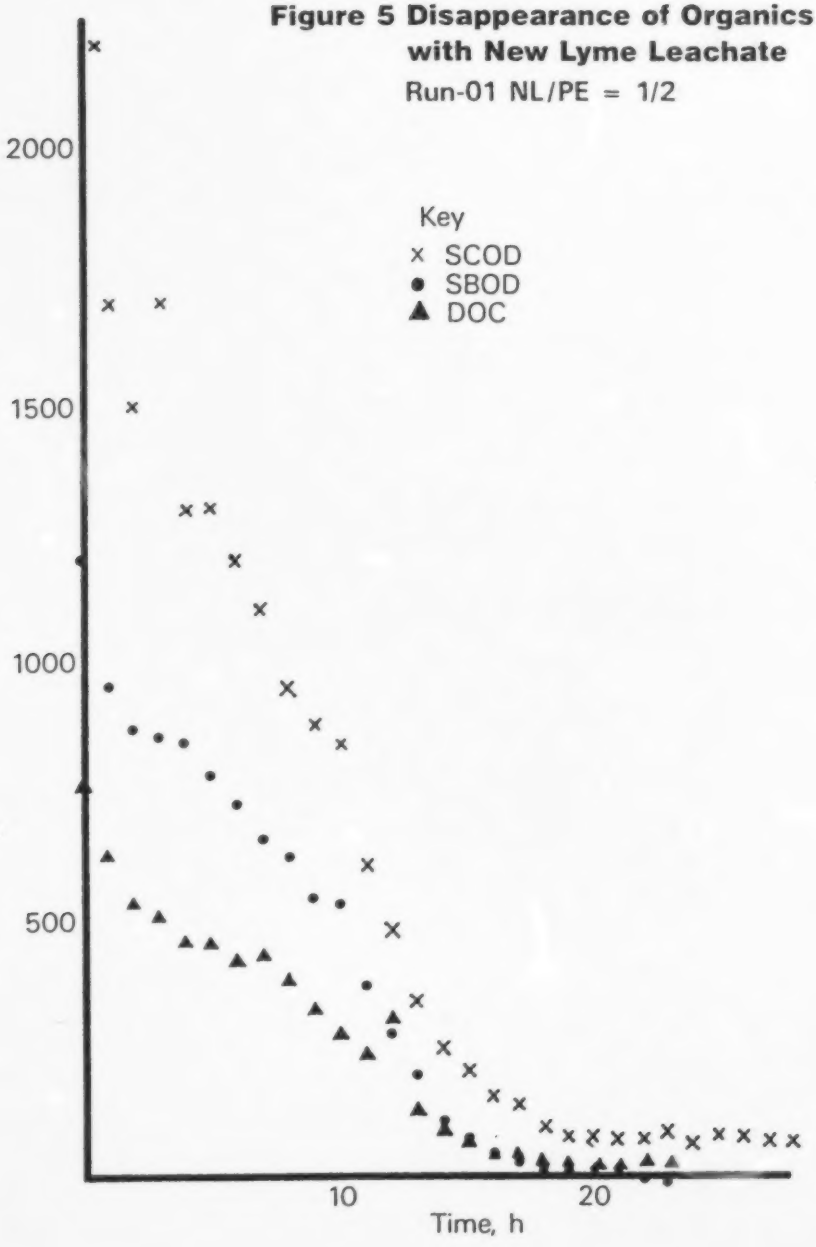
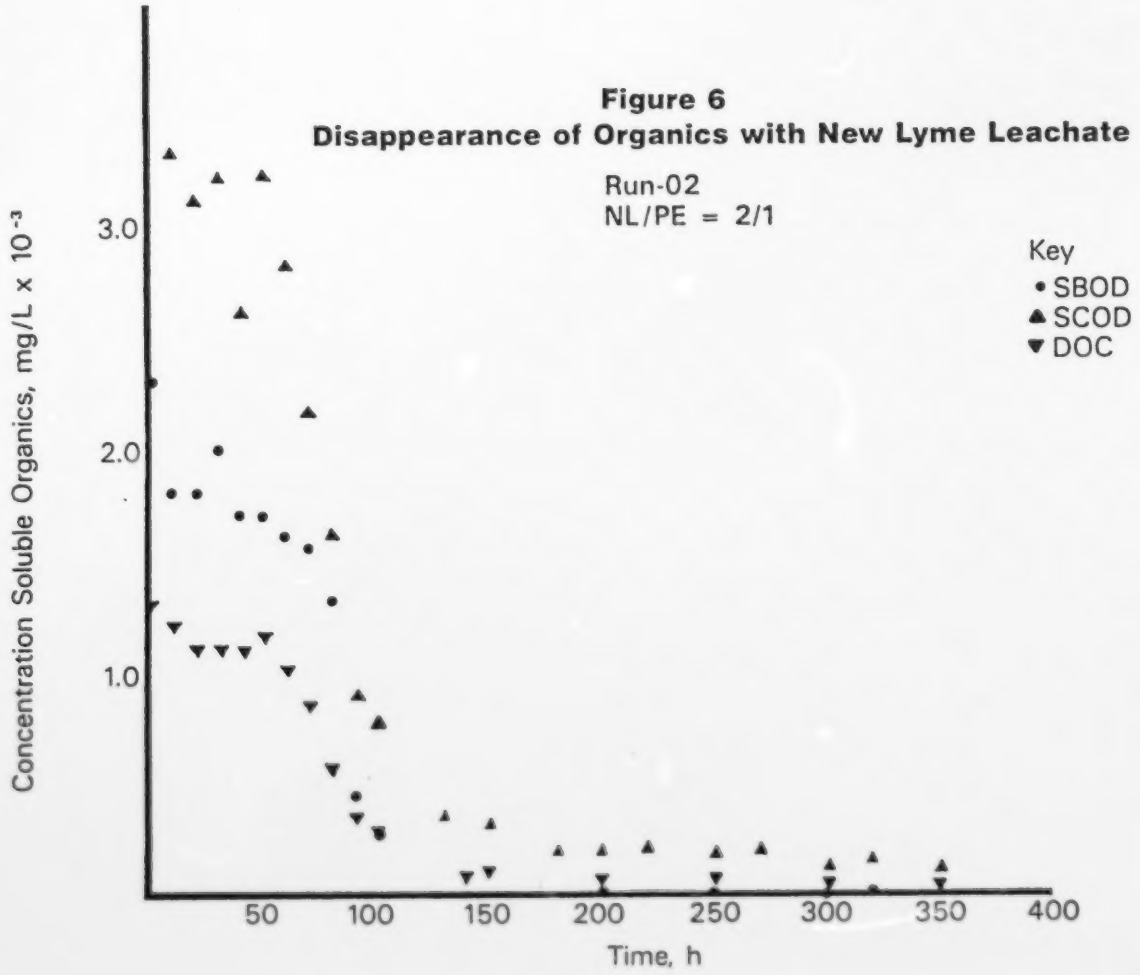


Figure 6
Disappearance of Organics with New Lyme Leachate



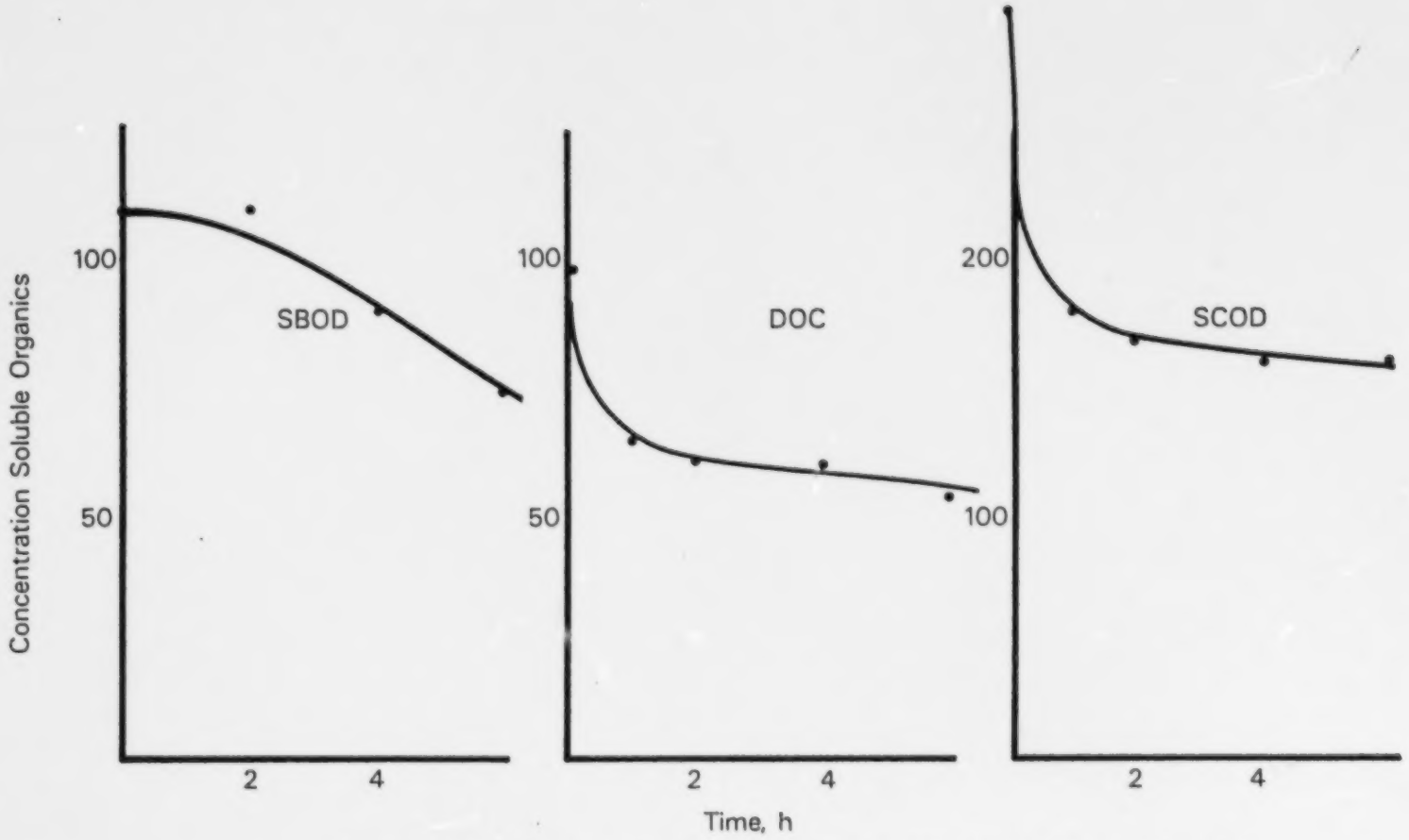


Figure 7 Disappearance of PE Organics After New Lyme Run-02

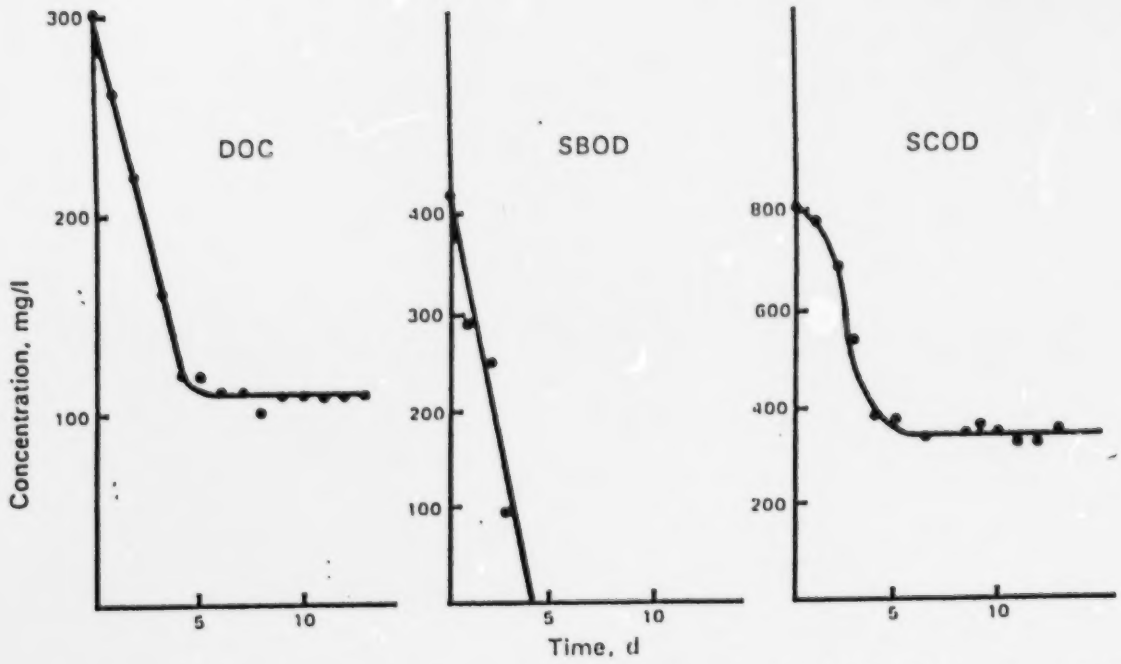


Figure 8 Disappearance of Organics for 100% Stringfellow Leachate